

# Comparing trapezius muscle activity in the different planes of shoulder elevation

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**Abstract.** [Purpose] The purpose of this study was to compare the upper, middle, and lower trapezius muscles' activity in the different planes of shoulder elevation. [Subjects] Twenty male subjects volunteered for this study. [Methods] Surface electromyographic (EMG) activity for each of the three regions of the trapezius muscles in the three different planes of elevation were collected while the participants maintained 30, 60, and 90 degrees of elevation in each plane. The EMG data were normalized with maximum voluntary isometric contraction (%MVIC), and compared among the planes at each angle of elevation. [Results] There were significantly different muscle activities among the elevation planes at each angle. [Conclusion] This study found that the three regions of the trapezius muscles changed their activity depending on the planes of shoulder elevation. These changes in the trapezius muscles could induce appropriate scapular motion to face the glenoid cavity in the correct directions in different planes of shoulder elevation.

**Key words:** Trapezius muscle, Plane of shoulder elevation, EMG

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## INTRODUCTION

Scapular motion is essential to ensure appropriate shoulder motions. The trapezius muscles contain upper, middle, and lower fibers (UT, MT, and LT)<sup>1)</sup>. They are activated with the serratus anterior muscle, and the force couple between these muscles contributes to scapular upward rotation<sup>2)</sup>. Some studies reported that individuals having shoulder pathology showed altered scapular motion<sup>3, 4)</sup> and altered scapular muscle activities<sup>5, 6)</sup>. Previous studies demonstrated that scapular muscle exercises were effective in reducing symptoms or improving function in patients with shoulder pathology<sup>7, 8)</sup>. A previous study reported that scapulohumeral kinematics differed among different planes of arm elevation<sup>9)</sup>. The different scapular motions could face the glenoid cavity in the plane of arm elevation to ensure appropriate glenohumeral joint contact. Appropriate glenohumeral joint contact is necessary to align shoulder muscles effectively, which helps to achieve the correct glenohumeral joint motion. Furthermore, a study that investigated three-dimensional acromioclavicular

distance (AHD) during arm elevation reported that the acromion and humeral articular surface were approximated at around 30 degrees of arm elevation, the minimal distance between the supraspinatus footprint on the greater tuberosity and the acromion was found at around 70 degrees of arm elevation, and the minimal AHD was found at around 90 degrees of arm elevation<sup>10)</sup>. The study suggested that arm elevation angles of less than 90 degrees were important when considering subacromial impingement syndrome. However, there have been few studies that have compared the three parts of trapezius muscles activity with arm elevation angles, that is, humerothoracic elevation angles, of less than 90 degrees in the different planes. Therefore, the purpose of this study was to compare the three parts of trapezius muscles activity among the different planes of arm elevation.

## SUBJECTS AND METHODS

Twenty healthy male subjects volunteered for this study (mean age, 21.9 years  $\pm$  0.8 years; mean height, 170.0 cm  $\pm$  4.1 cm; mean weight, 62.8 kg  $\pm$  5.5 kg). The exclusion criteria were shoulder pain and a history of orthopedic and/or neurological symptoms of the shoulder. All participants read and signed an informed consent form prior to participation in this study. This study was approved by the institutional review board of the Faculty of Health Sciences, Hokkaido University (ID: 13-18).

A MyoSystem 1200 (Noraxon USA Inc., Scottsdale, AZ,

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USA) was used to collect raw surface electromyography (EMG). In accordance with SENIAM guidelines<sup>11)</sup>, bipolar surface electrodes (Blue Sensor P-00-S, Ambu, Ballerup, Denmark) were placed over the UT, MT, and LT muscles with a 2 cm interelectrode distance, and a ground electrode was placed over the seventh cervical vertebra. Before placing the surface electrodes, the skin was cleaned in order to get a good electrode-skin contact. If necessary, the skin was shaved to reduce skin artifacts. This EMG unit provided a differential input impedance of greater than 10 M $\Omega$ , a gain of 1,000, a band-pass filter of 10–500 Hz, and a common mode rejection ratio of greater than 100 dB at 60 Hz. The sampling rate was set at 1,000 Hz. All raw EMG signals were transferred to a Windows computer through an analog/digital (A/D) converter at 1,000 Hz and a 16 bit A/D board. They were full-wave rectified and filtered with a 6th order Butterworth 6 Hz low-pass filter.

Before performing the series of tasks, EMG signals were collected during 3 trials of the maximal voluntary isometric contraction (MVIC) tests specified for each muscle of interest as described by SENIAM to allow for normalization of EMG measurements. During the MVIC tests, subjects performed and held each posture for 5 seconds against manual resistance in each trial. After signal filtering with a sixth order Butterworth 6 Hz low-pass filter, the EMG value of the middle one-second window of the 5 seconds was averaged for each trial. The mean of the trials was calculated and used as the normalization value.

The arm elevation tasks included in this study were 30, 60, and 90 degrees of elevation performed in the sagittal, scapular, and coronal planes, respectively. The scapular plane was defined as 30 degrees anterior to the coronal plane. A plastic pole was placed along the lateral aspect of the participants' arms to confirm and maintain each elevation plane. During all tasks, the subjects held a 1 kg dumbbell and maintained a thumb up position. Before data collection, the participants practiced the tasks several times without the dumbbell to familiarize themselves with the tasks. All subjects kept each elevation angle for 5 seconds and completed 3 trials of each task. To avoid muscle fatigue, they took a rest of 30 seconds between trials. For each task, the data were averaged for the EMG value of the middle three-second window of the 5 seconds the subjects maintained each elevation angle. Then, the data for each of the three trials were averaged within the same task. The results were normalized to the MVIC data (%MVIC), which were used to assess the activity of the UT, MT, and LT muscles in each task.

All statistical analyses were carried out using the PASW Statistics 18 software program (SPSS Inc., Chicago, IL, USA). A one-way repeated analysis of variance (ANOVA), with the Bonferroni multiple comparison procedure for post hoc analysis, was used to compare the muscle activities among the 3 planes at each elevation angle. The significance level was set at 0.05.

## RESULTS

The results of statistical analyses are described in Table 1. At 30 and 60 degrees of elevation, the UT activities were significantly greater in the coronal and scapular planes than in

**Table 1.** EMG data for each region of the trapezius muscle (%MVC) at 30, 60, and 90 degrees of arm elevation in each plane

	30°	Sagittal	Scapular	Coronal
UT	7.9±4.1	12.8±5.1*	12.9±4.6*	
MT	3.6±2.3	7.1±4.0*	8.7±4.2*†	
LT	9.9±7.6	5.1±4.1*	4.8±4.4*	
60°				
UT	11.0±5.6	21.5±9.3*	23.6±9.6*	
MT	5.1±3.1	11.3±5.9*	13.7±6.7*†	
LT	18.4±15.2	11.6±11.8*	7.3±6.2*	
90°				
UT	16.4±9.3	26.3±12.7*	30.1±13.2*†	
MT	6.4±4.5	13.8±10.8*	16.8±8.2*†	
LT	20.3±17.5	16.3±16.6*	13.3±10.5*	

UT: upper trapezius; MT: middle trapezius; LT: lower trapezius

\*Significant difference compared with sagittal plane elevation

†Significant difference compared with scapular plane elevation

the sagittal plane ( $p<0.05$ ). Regarding the MT muscle, there was significantly less activity in the sagittal plane than in the coronal and scapular planes ( $p<0.05$ ). Furthermore, the MT muscle activity in the coronal plane was significantly greater than those in the other two planes ( $p<0.05$ ). Concerning the LT muscle, sagittal plane elevation resulted in significantly greater muscle activity than in the other two elevation planes ( $p<0.05$ ).

At 90 degrees of elevation, there were significant differences of muscle activation in all three muscles ( $p<0.05$ ). The UT and MT muscles showed significantly greater activity during coronal plane elevation compared with both sagittal and scapular plane elevation ( $p<0.05$ ). Furthermore, scapular plane elevation resulted in significantly greater UT and MT muscle activities than sagittal plane elevation ( $p<0.05$ ). Regarding the LT muscle, there was a significant difference between sagittal and coronal plane elevation ( $p<0.05$ ).

## DISCUSSION

The main findings of this study were that there were significant differences in the muscle activities in the three regions of the trapezius muscles among the planes at each elevation angle, which were all within the range in which subacromial impingement can occur. To the best of our knowledge, there are few studies that have compared scapular muscle activity during shoulder elevation in the different planes of elevation.

A previous study, which investigated sternoclavicular joint kinematics during arm elevation in different planes, reported that the greatest clavicular elevation was found in sagittal plane elevation, followed by scapular plane elevation and then coronal plane elevation<sup>9)</sup>. The upper part of the trapezius attaches to the distal one-third of the clavicle<sup>12)</sup>. The current study demonstrated the greatest UT muscle activity during sagittal plane elevation, and greater UT muscle

activity was induced in scapular plane elevation compared with coronal plane elevation. These results suggested that the UT muscle activity might control clavicular motion according to the planes of elevation.

It has been reported that the greatest scapulothoracic joint internal rotation was found in sagittal plane elevation followed by scapular and then coronal plane elevations<sup>9)</sup>. The greatest amount of MT muscle activity was obtained in coronal plane elevation, followed by scapular and then sagittal plane elevation. Therefore, the MT muscle could affect adjustment of the scapulothoracic internal rotation depending on the planes of elevation.

Regarding the LT muscle, sagittal plane elevation induced greater LT muscle activity compared with the other two planes the elevation, and scapular plane elevation also induced greater LT muscle activity than coronal plane elevation. A previous study reported that acromioclavicular joint upward rotation was greater in sagittal plane elevation, and coronal plane elevation showed the least acromioclavicular upward rotation<sup>9)</sup>. The LT muscle attaches to the root of the scapula spine<sup>1, 12)</sup>. Taking the anatomical attachment region of the LT muscle and the acromioclavicular kinematics into account, the LT muscle activity depends on the elevation planes and could control the acromioclavicular joint upward rotation.

Previously, some studies have reported that abnormal scapular motion is related to shoulder pathology<sup>13–15)</sup> and that scapular muscle exercises reduce symptoms and improve function in patients with shoulder pathology<sup>7, 8)</sup>. This study suggested that each region of the trapezius muscle might control scapular motion in different planes of shoulder elevation. Therefore, trapezius muscle exercises are considered to be important for correction of scapular kinematics if patients having shoulder problems demonstrate scapular motion abnormality.

There are a few limitations in this study. First, this study analyzed trapezius muscle EMG recordings obtained during static arm elevation tasks, although the upper extremities are used dynamically in daily living. Secondly, this study did not collect EMG data for the serratus anterior muscle, which also contributes to scapular motion. These limitations should be considered in future studies. Thirdly, only healthy young people volunteered as subjects for this study. Collection of data from subjects having shoulder pathology or an aged population might provide insight concerning their treatment.

In addition, comparison of trapezius muscle activity at other angles and with different loads would develop the area of this study.

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